I, Yusuke Mizumoto, residing at 7-11-105, Tomihama 3-chome, Ichikawa-shi, Chiba 272-0115, Japan, and working for ISP Corporation of 1-29, Akashi-cho, Chuo-ku, Tokyo 104-0044, Japan, fully conversant with the English and Japanese languages, do hereby certify that to the best of my knowledge and belief the following is a true translation of Japanese Patent Application No. 2002-299783 filed in the Japanese Patent Office on the 15th day of October, 2002 in respect of an application for Letters Patent.

Signed, this 12th day of November, 2007

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[Name of Document] Specification

[Title of the Invention] Structure and method of coupling shaft member and cylindrical member

[Claims]

[Claim 1]

A coupling structure for a shaft member and a cylindrical member, which fixedly couples the cylindrical member fitted to an outer periphery of the shaft member at a predetermined fitted position, with the shaft member by caulking an outer periphery of the cylindrical member,

wherein the cylindrical member is formed out of a material greater in linear expansion coefficient than that of the shaft member, and an outer peripheral surface of the shaft member is formed with at least one of an axial groove and a circumferential groove, the at least one groove having a rectangular cross section having opposed faces substantially parallel to each other,

wherein an inner surface of the cylindrical member is deformed and in press contact with the opposed faces of the groove of the shaft member, by calking a portion of the cylindrical member corresponding to the groove of the shaft member after fitting the cylindrical member on the outer periphery of the shaft member.

[Claim 2]

The coupling structure for the shaft member and the cylindrical member as claimed in Claim 1, wherein the axial groove and the circumferential groove that are different in depth from each other are formed in the outer peripheral surface of the shaft member, wherein the caulked deformed inner surface of the cylindrical member is in press contact

with the opposed faces of the deeper groove at an intersection of the axial groove and the circumferential groove, by caulking a portion of the cylindrical member corresponding to the intersection.

[Claim 3]

The coupling structure for the shaft member and the cylindrical member as claimed in one of Claims 1 and 2, wherein the axial member is one of an input shaft and an output shaft arranged relatively rotatably with respect to the input shaft, the input shaft and the output shaft being used for a torque sensor of an electric power steering apparatus, wherein the cylindrical member is a surrounding member that is fixedly connected with an outer peripheral surface of the one of the input shaft and the output shaft and that is provided with a detection coil on its outer peripheral side.

[Claim 4]

A coupling method for a shaft member and a cylindrical member, which fixedly couples the cylindrical member fitted to an outer periphery of the shaft member at a predetermined fitted position, with the shaft member by caulking an outer periphery of the cylindrical member,

wherein the cylindrical member is formed out of a material greater in linear expansion coefficient than that of the shaft member, and an outer peripheral surface of the shaft member is formed with at least one of an axial groove and a circumferential groove, the at least one groove having a rectangular cross section having opposed faces substantially parallel to each other,

wherein an inner surface of the cylindrical member is deformed and in press contact with the opposed faces of the groove of the shaft member, by calking a portion of the cylindrical member corresponding to the groove of the shaft member after positioning and fitting the cylindrical member on the outer periphery of the shaft member.

[Detailed description of the invention]

[0001]

[Technical Field of the invention]

The present invention relates to structure and method of coupling a shaft member with a cylindrical member. For example, the shaft member is an input shaft or an output shaft for a torque sensor used for an electric power steering apparatus, and the cylindrical member is a surrounding member which is fixed to an outer periphery of the input shaft or the output shaft by caulking.

[0002]

[Conventional Art]

As a conventional structure of coupling a shaft member with a cylindrical member, for example, the structure disclosed in the following Patent Document 1 is known.

[0003]

As an outline of this document, the coupling structure is applied to a torque sensor of an electric power steering apparatus to couple an output shaft and a cylindrical member fixed thereto by caulking. The torque sensor has axial grooves and a circumferential groove formed in the outer peripheral surface of a large-diameter portion arranged at an end portion of the output shaft. The axial grooves axially extend between both ends of the large-

diameter portion, whereas the circumferential groove circumferentially extends and roughly corresponds to a position of an end portion of the cylindrical member when fixing the cylindrical member.

[0004]

Semispherical protrusions are formed on the inner peripheral surface of the cylindrical member at the position slightly inward of the lower end. The number and the positions of the protrusions correspond to those of the axial grooves of the output shaft, and the height of each of the protrusions is substantially equal to the depth of the corresponding axial groove.

[0005]

When fixing the cylindrical member to the large-diameter portion of the output shaft; at first, the protrusions of the cylindrical member are engaged in the axial grooves of the output shaft to push the cylindrical member to the output shaft. Then, tip portions of the protrusions are urged to move in coming in press contact with bottom portions of the axial grooves. This allows a circumferential positioning of the cylindrical member with respect to the output shaft. Then, the cylindrical member is further pushed to the output shaft so as to bring the end portion of cylindrical member close to the circumferential groove. In this state, the end portion of the cylindrical member is caulked inwardly to engage in the circumferential groove, so that the cylindrical member is fixed to the large-diameter portion of the output shaft.

[0006]

[Patent Document 1] Japanese Patent Application Publication No. 1999(H11)-248562 (see paragraphs 0016 and 0017, Figs. 2 and 5)

[0007]

[Problem which the invention is intended to solve]

In the above torque sensor, however, when fixing the cylindrical member to the output shaft; the respective protrusions of the cylindrical member are fitted in the axial grooves of the output shaft, and then the cylindrical member is pushed strongly to the output shaft. Thus, there is a fear that the cylindrical member might be deformed upon this pushing.

[0008]

Specifically, as being mainly formed of a thin aluminum-alloy material as conductive non-magnetic material, the cylindrical member is low in rigidity and thus strength. As mentioned above, when press-fitting the cylindrical member to the output shaft, for example, the cylindrical member is held and pushed so that the outer periphery of the cylindrical member receives a load in its diameter reducing direction. Thus, there is a possibility that the cylindrical member produces plastic deformation, leading to occurrence of distortion. This changes a shape of magnetic path, resulting in a reduction in torque detection accuracy obtained by the torque sensor.

[0009]

The present invention is devised in consideration of the above-mentioned technical problem. Therefore, it is an object of the present invention to provide a coupling structure and method, which does not apply a large

pressure to a cylindrical member from the outside when combining the cylindrical member with an input shaft or an output shaft, and which allows strong coupling between the shaft and the cylindrical member even when having a change in atmospheric temperature.

[0010]

[Means for solving the Problem]

To achieve the above-described object, according to the invention recited in Claim 1, the cylindrical member is formed out of a material greater in linear expansion coefficient than that of the shaft member, and an outer peripheral surface of the shaft member is formed with at least one of an axial groove and a circumferential groove, the at least one groove having a rectangular cross section having opposed faces substantially parallel to each other, wherein an inner surface of the cylindrical member is deformed and in press contact with the opposed faces of the groove of the shaft member, by calking a portion of the cylindrical member corresponding to the groove of the shaft member after fitting the cylindrical member on an outer periphery of the shaft member.

[0011]

According to the invention recited in this Claim 1, when assembling the cylindrical member to the shaft member, the cylindrical member is slidably engaged on the outer peripheral surface of the shaft member by a predetermined length in loose fit and not in press fit. Then, the cylindrical member is caulked from the outside at a forming position of the axial groove or the circumferential groove.

[0012]

Further, the cylindrical member is formed out of a material (aluminum-alloy material, for example) which is greater in linear expansion coefficient than a material (iron material, for example) of the shaft member. Thus, when caulking the cylindrical member at an ordinary temperature, the deformed inner surface of the caulked portion is in press contact with the opposed faces of the groove of the shaft member, obtaining strong coupling by great friction resistance (interference).

[0013]

When the atmospheric temperature is low, the cylindrical member is greater in contraction-deformation amount than the shaft member, thus obtaining the whole inner peripheral surface of the cylindrical member in press contact with the outer periphery of the shaft member. Moreover, the friction resistance is slightly reduced between the both inner surfaces of the caulked portion and the opposed faces of the groove facing the both inner surfaces, whereas the friction resistance is increased between a bottom of the caulked portion and a bottom of the groove facing the bottom of the caulked portion in accordance with radial contraction deformation of the members, obtaining a sufficient tightening force (coupling force) at the caulked portion.

[0014]

On the other hand, when the atmospheric temperature is high, a tightening force to the outer peripheral surface of the shaft member is reduced by deformation of the cylindrical member in the diameter increasing direction, whereas the friction resistance is increased between the

both inner surfaces of the caulked portion and the opposed faces of the groove, obtaining a strong coupling force.

[0015]

According to the invention recited in Claim 2, the axial groove and the circumferential groove that are different in depth from each other are formed in the outer peripheral surface of the shaft member, wherein the caulked deformed inner surface of the cylindrical member is in press contact with the opposed faces of the deeper groove at an intersection of the axial groove and the circumferential groove, by caulking a portion of the cylindrical member corresponding to the intersection.

[0016]

According to such a recited invention, the caulking is carried out at a deep-groove position of the intersection of the axial groove and the circumferential groove, so that the caulked portion is engaged in the grooves with the whole inner surface of caulked portion conforming to the shapes of the circumferentially-opposed faces and bottom of the deep groove. Therefore, when the atmospheric temperature is particularly high, the caulked portion also produces expansion deformation, so that the whole inner surface of the caulked portion is in press contact with the opposed faces of the deep groove to generate a great friction resistance, obtaining strong coupling of the cylindrical member to the shaft member. This allows sure prevention of axial and circumferential free rotations of the cylindrical member.

[0017]

According to the invention recited in Claim 3, the axial member is one of an input shaft and an output shaft arranged relatively rotatably with respect to the input shaft, the input shaft and the output shaft being used for a torque sensor of an electric power steering apparatus, and the cylindrical member is a surrounding member that is fixedly connected with an outer peripheral surface of the one of the input shaft and the output shaft and that is provided with a detection coil on its outer peripheral side.

[0018]

According to such a recited invention, plastic deformation of the surrounding member is prevented from occurring during assembling of the surrounding member to the input shaft or the output shaft. Moreover, the surrounding member can be strongly coupled to the input shaft or the output shaft when having a change in atmospheric temperature of the torque sensor, preventing positional displacement, resulting in restraint of a reduction in detection accuracy obtained by the torque sensor.

[0019]

According to the invention recited in Claim 4 that is a coupling method of a cylindrical member to a shaft member, the cylindrical member is formed out of a material greater in linear expansion coefficient than that of the shaft member, and an outer peripheral surface of the shaft member is formed with at least one of an axial groove and a circumferential groove, the at least one groove having a rectangular cross section having opposed faces substantially parallel to each other, wherein an inner surface of the cylindrical member is deformed and in press

contact with the opposed faces of the groove of the shaft member, by calking a portion of the cylindrical member corresponding to the groove of the shaft member after positioning and fitting the cylindrical member on the outer periphery of the shaft member.

[0020]

According to such a recited invention, the cylindrical member is simply fitted on the shaft member but not press fitted thereon, and then it is subjected to caulking process, achieving simplified assembling, resulting in restraint of increased manufacturing cost.

[0021]

Moreover, the inner surface of the caulked portion is tightly engaged, for example, on the opposed faces of the axial groove or the circumferential groove having rectangular cross section. Thus, even if the cylindrical member produces deformation in the diameter decreasing or increasing direction in accordance with a change in atmospheric temperature, a great friction resistance is ensured at the caulked portion, obtaining a strong holding state.

[0022]

[Embodiments of the invention]

Now, referring to the drawings, a description is made about an embodiment of a structure and method of coupling a shaft member with a cylindrical member according to the present invention. In the embodiment, the present invention is applied to a torque sensor for an electric power steering apparatus.

[0023]

FIG. 1 is a schematic view showing the electric power steering apparatus to which torque sensor TS according to this embodiment is applied. As shown in FIG. 1, when rotating a steering wheel SW with hands, rotation of a rotation shaft S is converted into linear motion of a rack R through rack R and a pinion P, allowing a change in orientation or steering of right and left front wheels TL and TR. Moreover, pinion P is constructed to be rotatable by an electric motor M through a reduction gear G, providing assistance to a steering force produced manually as described above.

[0024]

Electric motor M is controlled by a microcomputer of a vehicle-mounted electronic control unit ECU in accordance with a signal out of torque sensor TS for sensing a manual steering force, thus carrying out an assistance control of the manual steering force. In FIG. 1, there are also provided a fail-safe relay Ry and a vehicle-mounted battery B.

[0025]

The torque sensor TS is configured as shown in FIGS. 2-10. FIG. 2 is a longitudinal sectional view showing torque sensor TS for the electric power steering apparatus for vehicle, and FIG. 3 is an exploded perspective view showing the electric power steering apparatus. Referring to FIGS. 2 and 3, there are provided a housing 1, an input shaft or shaft member 2, an output shaft 3, a torsion bar or elastic body 4, a member to be surrounded 5, a torque-detection-side surrounding member or cylindrical member 6 which serves as a magnetic-path blocking part, a

temperature-compensation-side surrounding member 7 which serves as a magnetic-path blocking part, a coil for detecting torque or detection coil 8, a temperature compensation coil 9 which is another detection coil, a spacer 10, a base member 11, a disc spring 12, an output-shaft-side worm wheel 13, and a motor-shaft-side worm shaft 14.

[0026]

Housing 1 includes three divided portions, i.e. an upper housing 110 for mainly accommodating torque sensor TS, a central housing 120 for mainly accommodating reduction gear G, and a lower housing 130 for mainly accommodating rack R and pinion P. The three housings 110, 120, 130 are assembled axially to form the unity of housing 1.

[0027]

Specifically, a lower-end opening edge 121a of upper housing 110 is inserted into a large-diameter portion 120a of central housing 120 located at the upper part of central housing 120, and a flange 121b of upper housing 110 is engaged on an opening upper-end face of central housing 120. Under this contacted state, upper housing 110 and central housing 120 are connected and fixed with each other through a bolt or the like.

[0028]

Moreover, a small-diameter portion 120b of central housing 120 located at the lower part of central housing 120 is mounted in a large-diameter portion 130a of lower housing 130 located at the upper end of lower housing 130, and the upper end face of large-diameter portion 130a is engaged on an annular stepped face 120c of central

housing 120. Under this contacted state, central housing 120 and lower housing 130 are connected and fixed with each other through a bolt or the like

[0029]

Input shaft 2 and output shaft 3 are coaxially disposed in housings 110, 120, and 130 so as to be rotatably supported through respective bearings 1a, 1b, and 1c.

[0030]

Torsion bar 4 is rotatably inserted into a center hole 2a of input shaft 2, and has one end fixed to input shaft 2 through a pin 2b at the depth side of center hole 2a and another end press-fitted into a center hole 3a of output shaft 3.

[0031]

Moreover, steering wheel SW is connected to input shaft 2. A steering force of this steering wheel SW is provided through input shaft 2, torsion bar 4, and output shaft 3 to rack R and pinion P arranged at the lower end of output shaft 3, wherein it is converted into a linear motion of rack R and transmitted to right and left front wheels TL and TR.

[0032]

Surrounded member 5 serves to form a path of magnetic field generated by torque detection coil 8 and temperature compensation coil 9, and is formed out of a magnetic material such as stainless steel by sintering process. Member 5 is press-fit coupled to the outer periphery of a small-diameter portion 33 arranged in upper housing 110 and at the upper end (input-shaft 2 side end) of output shaft 3 by forming an annular stepped face 32

with respect to a main body 31. (see FIG. 5) As shown in the detailed perspective view of FIG. 4, surrounded member 5 has, at the outer periphery side of a surrounded member 5's annular base having in its center a coupling hole 50 for press-fit coupling to small-diameter portion 33, a plurality of (eight in the embodiment) recessed parts 51 formed to axially penetrate and at predetermined circumferential intervals and non-recessed parts (magnetic-path forming parts) 52. A serration 50a is integrally formed on the inner peripheral surface of coupling hole 50 during sintering process of surrounded member 5.

[0033]

Torque detection coil 8 serves to detect torque acting between input shaft 2 and output shaft 3 in accordance with an impedance change. Referring to FIGS. 2 and 3, while axially facing an input-shaft-side face of surrounded member 5, torque detection coil 8 is fixed to upper housing 110 through a yoke member 80 for surrounding coil 8 except its lower face. Thus, a magnetic field is generated by allowing surrounded member 5 and yoke member 80 to be magnetic path.

[0034]

Referring to FIG. 5, yoke member 80 includes an upper-face surrounding part 80a constituting a main body of gate-shaped cross section for surrounding torque detection coil 8 except its lower face opposite to surrounded member 5, an inner-periphery surrounding part 80b, an outer-periphery surrounding part 80c, and a stationary flange part 80d protruding outwardly from a lower-end opening edge of outer-periphery surrounding part 80c. Outer-periphery

surrounding part 80c from which stationary flange part 80d protrudes outwardly is greater in thickness than upper-face surrounding part 80a and inner-periphery surrounding part 80b so as to prevent leakage of magnetic flux toward stationary flange part 80d.

[0035]

Temperature compensation coil 9 serves to correct a variation in value of torque detected by torque detection coil 8 due to temperature change. Facing axially an output-shaft 3's side face of surrounded member 5, temperature compensation coil 9 is fixed to upper housing 110 through a yoke member 90 for surrounding coil 9 except its upper face, generating a magnetic field having surrounded member 5 and yoke member 90 as magnetic path.

[0036]

Referring to FIG. 5, yoke member 90 includes a lower-face surrounding part 90a constituting a main body of gate-shaped cross section for surrounding temperature compensation coil 9 except its upper face opposite to surrounded member 5, an inner-periphery surrounding part 90b, an outer-periphery surrounding part 90c, and a stationary flange part 90d protruding outwardly from an upper-end opening edge of outer-periphery surrounding part 90c. Outer-periphery surrounding part 90c from which stationary flange part 90d protrudes is greater in thickness than upper-face surrounding part 90a and inner-periphery surrounding part 90b so as to prevent leakage of magnetic flux toward stationary flange part 90d.

[0037]

Spacer 10 is interposed between yoke member 80 of the side of torque detection coil 8 and yoke member 90 of the side of temperature compensation coil 9 to determine an axial clearance therebetween. Spacer 10 includes double rings, i.e., inner and outer rings 20 and 21.

[0038]

Specifically, referring to FIGS. 6 and 7, spacer 10 is formed out of an aluminum-alloy material as non-magnetic metallic material, and includes double cylinders composed of cylindrical outer ring 20 and cylindrical inner ring 21 press fitted in outer ring 20 along the inner peripheral surface of outer ring 20. Outer ring 20 has a thickness smaller than that of inner ring 21, and a vertical width W of outer ring 21 greater than a vertical width W1 of inner ring 21. On the other hand, inner ring 21 is shaped like a simple cylinder, and is press fitted into outer ring 20 up to the vicinity of the bottom end of an inner peripheral surface 20a of outer ring 20. Inner ring 21 has an upper end formed with an annular stepped face 21a to axially position and engage stationary flange part 80d of yoke member 80, and a lower end formed with an annular stepped face 21b to axially position and engage stationary flange part 90d of yoke member 90.

[0039]

Thus, the axial length of inner ring 21 between both annular stepped faces 21a and 21b defines an axial positional relationship between torque detection coil 8 and temperature compensation coil 9.

[0040]

Moreover, axial protrusions 22 and 23 are formed at the upper and lower ends of inner peripheral surface 20a of outer ring 20 by inward press caulking, as engaging portions for circumferentially positioning and engaging yoke members 80 and 90. On the other hand, recesses 80e and 90e are formed through the outer peripheral surface of both stationary flange parts 80d and 90d, with which axial protrusions 22 and 23 are engaged. These both recesses 80e and 90e are arranged to circumferentially correspond to circumferential alignments of respective coil harnesses 8a and 9a with respect to the direction of protrusions of coil harnesses 8a and 9a. Both axial protrusions 22 and 23 are also formed to circumferentially correspond to the circumferential alignments of respective coil harnesses 8a and 9a. Namely, axial protrusions 22 and 23 and recesses 80e and 90e constitute the relative-rotation preventing means in the Claims.

[0041]

The base member 11 is mounted so as to cause a lower flange part 11a thereof to be engaged on an engagement step 120d formed inside large-diameter portion 120a of central housing 120. An annular concave 11c is formed inside an upper small-diameter cylindrical part 11b of base member 11 to accommodate the main body of yoke member 90. The small-diameter cylindrical part 11b is inserted through a lower-end opening of the spacer 10 to have an upper end face on which stationary flange part 90d of yoke member 90 abuts and is fixed. Thus, the axial length of base member 11 defines an axial positional relationship between central housing 120 (housing 1) and

torque detection coil 8 and temperature compensation coil 9.

[0042]

A recess 11d in which axial protrusion 23 of spacer 10 is engaged is formed in the outer peripheral surface of small-diameter cylindrical part 11b. With axial protrusion 23 engaged in this recess 11d, the protruding position of coil harness 9a is circumferentially aligned with a harness leading groove 11e formed in base member 11.

[0043]

As shown in FIGS. 6 and 7, pairs of positioning protrusions 24a and 24b are integrally formed at the upper end of outer ring 20 of the spacer 10 in the 180° circumferentially angularly distant positions. These positioning protrusions 24a and 24b are obtained by outwardly cutting and bending the parts of upper end of outer ring 20 by means of a press so as to provide a roughly C-shaped cross section as viewed in plan. On the other hand, an axial engagement groove 122 in which each of the positioning protrusions 24a and 24b is engaged is formed in the inner peripheral surface of upper housing 110 radially opposite to the each of positioning protrusions 24a and 24b. With each of positioning protrusion 24a and 24b engaged in axial engagement groove 122, the leading direction of coil harnesses 8a and 9a is circumferentially aligned with a wiring leading groove 110e formed at one side of upper housing 110. That is, positioning protrusion 24a, 24b and axial engagement groove 122 serve to prevent relative rotation between upper housing 110 and spacer 10.

[0044]

With disc spring 12 interposed between stationary flange part 80d and an annular step 110b formed inside upper housing 110 and in the axially middle position of upper housing 110, upper housing 110 is assembled and fixed to central housing 120 by a bolt and the like. Thereby, while preventing the positional deviations of yoke members 80 and 90 (torque detection coil 8 and temperature compensation coil 9) by means of a biasing force of disc spring 12, and maintaining an axial positional relationship thereof; yoke members 80 and 90 are assembled to housing 1.

[0045]

The torque-detection-side surrounding member 6 is integrally formed out of an aluminum-alloy material as conductive non-magnetic metallic material. Surrounding member 6 is fixed to input shaft 2 by caulking an after-mentioned inner-periphery-side cylinder 60 on the outer periphery of input shaft 2 formed out of a ferrous metallic material of lower linear expansion coefficient than that of surrounding member 6.

[0046]

Specifically, referring to FIG. 8, input shaft 2 has a circumferential groove 2d of roughly rectangular cross section formed in the outer peripheral surface of a maximum outer-diameter portion 2c arranged relatively close to the lower end of input shaft 2, and a plurality of axial grooves 2e of roughly rectangular cross section formed axially in maximum outer-diameter portion 2c. Circumferential groove 2d is formed roughly in the

longitudinal center of maximum outer-diameter portion 2c, whereas three axial grooves 2e are formed at the 120° circumferentially angularly distant positions of maximum outer-diameter portion 2c also as shown in FIG. 10. Referring to FIGS. 10 and 11, each of three axial groove 2e is greater in depth than circumferential groove 2d. A concave 2f is formed at the position of intersection of both grooves 2d and 2e. Circumferential groove 2d and axial groove 2e are of a roughly rectangular cross section to provide opposed faces 2h, 2h and 2i, 2i respectively parallel to each other along the length direction.

[0047]

Also as shown in FIG. 9, torque-detection-side surrounding member 6 includes a roughly disc-shaped main body 6a and an inner-periphery-side cylinder 60 integrated with main body 6a in the center of main body 6a. Inner-periphery-side cylinder 60 is fitted over the outer peripheral surface of maximum outer-diameter portion 2c of input shaft 2. Referring to FIGS. 10-15, by driving a caulker 81 such as a punch to inner-periphery-side cylinder 60 at the position corresponding to the position of intersection of both grooves 2d and 2e, i.e. concave 2f and a part of circumferential groove 2d around concave 2f; inner-periphery-side cylinder 60 has caulked part 60a and its part 60b that are tightly fitted in concave 2f and the part of circumferential groove 2d around concave 2f under depressed state. With this, torque-detection-side surrounding member 6 is circumferentially axially positioned with respect to input shaft 2 for fixing thereto. Referring to FIGS. 14, 15A and 15B, caulker 81 has a tip

portion 81a formed roughly flat so as to conform to circumferential groove 2d, and a tip edge 81b formed circularly along the circular shape of circumferential groove 2d. Inner-periphery-side cylinder 60 has three caulked spots which are about 120° circumferentially angularly distant from each other.

[0048]

By fixing inner-periphery-side cylinder 60 to input shaft 2 as described above, torque-detection-side surrounding member 6 is interposed between surrounded member 5 and torque detection coil 8 with a predetermined clearance. In detail as shown in FIGS. 16-18, a plurality of (eight in the embodiment) windows (recesses) 61 having the number corresponding to that of recessed parts 51 and non-recessed parts 52 of surrounded member 5 are axially formed through surrounding member 6 at predetermined circumferential intervals. The circumferential width of each window 61 is equal to the width of non-recessed part 52 of surrounded member 5.

[0049]

Torque produced between input shaft 2 and output shaft 3 is detected by detecting a change in superimposition between windows 61 or non-recessed parts 62 of torque-detection-side surrounding member 6, and recessed parts 51 or non-recessed parts 52 of surrounded member 5 in accordance with an impedance change.

[0050]

Temperature-compensation-side surrounding member 7 is interposed between surrounded member 5 and temperature compensation coil 9. Surrounding member 7

has an inner periphery unrestricted or not fixed to output shaft 3, and an outer periphery formed with an outer cylinder (connecting portion) 73 which extends axially for integral coupling to an outer cylinder (connecting portion) 63 of torque-detection-side surrounding member 6 which also extends axially. This allows unitary rotation of two surrounding members 6 and 7.

[0051]

As shown in FIG. 16, window 61 of torque-detection-side surrounding member 6 and a window 71 of temperature-compensation-side surrounding member 7 are disposed with 222 degree rotational angle offset with each other. With no torque being applied to input shaft 2 side, i.e. a torque value being zero, the width of non-recessed part 62 or 72 located between window 61 of torque-detection-side surrounding member 6 and window 71 of temperature-compensation-side surrounding member 7 is equal to the circumferential width of non-recessed part 52 of surrounded member 5. Non-recessed part 52 of surrounded member 5 is axially just overlapped with this width portion.

[0052]

Referring to FIG. 18, each window 71 of temperature-compensation-side surrounding member 7 has a center-side portion formed like a recess communicating with a center hole (through hole) 74, which allows the annular base and non-recessed parts (magnetic-path forming parts) 52 of surrounded member 5 to axially pass through temperature-compensation-side surrounding member 7.

[0053]

Maximum outer-diameter portion 2c of input shaft 2 has a diameter smaller than the inner diameters of inner-periphery-side cylinder 60 of torque-detection-side surrounding member 6, coupling hole 50 of surrounded member 5, and yoke members 80 and 90 for accommodating torque detection coil 8 and temperature compensation coil 9. This allows the assembling of those sensor members from the side of input shaft 2.

[0054]

Next, a procedure of assembling the respective members is described.

(A) Output shaft 3 having a bearing 1b press-fitted therein is inserted into central housing 120 from below to press-fit the bearing 1b to the inner surface of small-diameter portion 120b, thus assembling the middle portion of output shaft 3 to central housing 120 so as to be rotatably supported thereby. With torsion bar 4 having a lower end spline-engaged in center hole 3a of output shaft 3 and an upper end inserted into center hole 2a of input shaft 2, a pin-mounting hole 2g is formed to extend through torsion bar 4 and input shaft 2 in the diameter direction. A pin 2c is press fitted into this mounting hole 2g to fix the upper end of torsion bar 4 to input shaft 2. After removing cutting oil and chips produced during formation of pin-mounting hole 2g, the assembling proceeds to a next process.

(B) When small-diameter portion 120b of central housing 120 is inserted into large-diameter portion 130a of lower housing 130, pinion P is engaged with rack R by rotating output shaft 3. Finally, the lower end of output

shaft 3 is press-fitted into bearing 1c press-fitted into lower housing 130, thus assembling the lower end of output shaft 3 to lower housing 130 so as to be rotatably supported thereby.

(C) Worm wheel 13 is press-fitted to output shaft 3 in central housing 120.

(D) Base member 11 is assembled so as to engage lower flange part 11a of base member 11 on annular step 120d formed in large-diameter portion 120a of central housing 120.

(E) Yoke member 90 (temperature compensation coil 9) is assembled to allow the main body of yoke member 90 to be accommodated in annular concave 11c of base member 11, and to allow stationary flange part 90d to abut and engage on the upper end face of upper small-diameter cylindrical part 11b of base member 11.

(F) Surrounded member 5 is assembled to upper smaller-diameter portion 33 of output shaft 3 by press-fitting the coupling hole 50 thereto. At that time, a clearance between temperature compensation coil 9 and surrounded member 5 is measured by using a sensor and the like, and thereby the axial positioning of surrounded member 5 is carried out.

(G) Torque-detection-side surrounding member 6 integrated with temperature-detection-side surrounding member 7 through outer cylinders 63 and 73 is fixed to maximum outer-diameter portion 2c of input shaft 2 through inner-periphery-side cylinder 60 by caulking as described above. At that time, since a slight clearance exists between inner-periphery-side cylinder 60 and

maximum outer-diameter portion 2c of input shaft 2, surrounding member 6 is loosely fitted to the outer periphery of maximum outer-diameter portion 2c.

[0055]

At that time, as described above, the annular base and non-recessed part (magnetic-path forming part) 52 of surrounded member 5 can axially pass through temperature-detection-side surrounding member 7. Thus, temperature-detection-side surrounding member 7 is axially disposed to form a predetermined clearance between surrounded member 5 and temperature compensation coil 9. And surrounding member 7 is circumferentially disposed so that the difference is zero between impedance detected by torque detection coil 8 and that detected by temperature compensation coil 9, i.e. the magnetic field is completely blocked by non-recessed parts 62 and 72 of torque-detection-side and temperature-compensation-side surrounding members 6 and 7.

[0056]

In this state, part of inner-periphery-side cylinder 60 is driven into concave 2f by caulker 81 as shown in FIGS. 9-14 so as to tightly engage caulked part 60a and its part 60b in circumferential groove 2d and concave 2f. Specifically, caulked part 60a produces plastic deformation to tightly engage with opposed faces 2h and 2h of circumferential groove 2d, whereas its part 60b produces plastic deformation to tightly engage with four opposed faces of concave 2f. This allows axial and circumferential positioning and firm fixing of torque-detection-side and

temperature-detection-side surrounding members 6 and 7 with respect to input shaft 2.

(H) Spacer 10 is assembled under the state where downward annular stepped face 21b abuts and engages on the upper face of stationary flange part 90d of yoke member 90 of the side of temperature compensation coil 9. At that time, axial protrusion 23 of spacer 10 is engaged in recess 90e of stationary flange part 90d and recess 11d of base member 11 to circumferentially position the spacer 10. This allows circumferential alignment of coil harness 9a of temperature compensation coil 9 and harness leading groove 11e of base member 11.

(I) Yoke member 80 (torque detection coil 8) is assembled under the state where stationary flange part 80d is engaged on upward annular stepped face 21a of spacer 10. At that time, axial protrusion 22 of spacer 10 is engaged in recess 80e of stationary flange part 80d to circumferentially position the yoke member 80. This allows arrangement of torque-detection-side surrounding member 6 between surrounded member 5 and torque detection coil 8 with a predetermined clearance due to a preset interval between both annular stepped faces 21a and 21b, and allows circumferential alignment of protrusions of both coil harnesses 8a and 9a of torque detection coil 8 and temperature compensation coil 9.

(J) Upper housing 110 is assembled to central housing 120 under the state where disc spring 12 is disposed on stationary flange part 80d of yoke member 80.

[0057]

Specifically, input shaft 2 is press-fitted into bearing 1a press-fitted in the center hole of upper housing 110 to be rotatably supported to upper housing 110. Lower-end opening edge 121a of upper housing 110 is inserted into large-diameter portion 120a arranged in the upper part of central housing 120, and flange 121b of upper housing 110 is engaged on the upper end face of the opening of central housing 120. In this state, upper and central housings 110 and 120 are axially fixed by a bolt and the like to have disc spring 12 compressed between stationary flange part 80d and annular step 110d, which provides a strong reaction force to axially hold and fix yoke member 80, spacer 10, yoke member 90, and base member 11 between disc spring 12 and annular step 110d. Upon assembling of upper housing 110, the positioning protrusions 24a and 24b formed on the outer periphery of spacer 10 are engaged in axial engagement groove 122 in the inner peripheral surface of upper housing 110. This allows circumferential alignment of the protruding direction of coil harnesses 8a and 9a and wiring box 110e formed at one side of upper housing 110.

[0058]

Next, operations and effects of torque sensor TS will be described.

[0059]

In this embodiment, torque sensor TS is constructed as described above, so that when torque is zero, the magnetic field is completely blocked by respective non-recessed parts 62 and 72 of torque-detection-side and temperature-compensation-side surrounding members 6 and 7. As a

result, the difference is roughly zero between an impedance value detected by torque detection coil 8 and that detected by temperature compensation coil 9 (i.e. torque value is zero).

[0060]

When torque increases from zero-torque value to act on input shaft 2, torsion bar 4 is twisted in accordance with a torque amount when torque of input shaft 2 is transmitted to output shaft 3 through torsion bar 4, causing relative rotation of surrounded member 5 and torque-detection-side surrounding member 6. With this, non-recessed parts of surrounded member 5 produce relative rotation in the direction to coincide with windows 61 of torque-detection-side surrounding member 6, so that an impedance value detected by torque detection coil 8 varies with the relative rotation amount. On the other hand, non-recessed parts of surrounded member 5 produce relative rotation in the direction to coincide with non-recessed parts 72 of temperature-compensation-side surrounding member 7. That is, two impedance values vary in the reverse direction, i.e. in the plus and minus directions with respect to roughly zero impedance difference.

[0061]

Then, detection of a differential value between a plus-direction impedance value detected by torque detection coil 8 and a minus-direction impedance value detected by temperature compensation coil 9 can provide a torque value as always temperature compensated. Moreover, it can provide a greater value as a differential value between two impedance values respectively detected by torque

detection coil 8 and temperature compensation coil 9, resulting in enhancement in torque detection accuracy.

[0062]

Further, in the embodiment, maximum outer-diameter portion 2c of input shaft 2 is smaller than the inner diameters of inner-periphery-side cylinder 60 of torque-detection-side surrounding member 6, coupling hole 50 of surrounded member 5 fixed to output shaft 3, and yoke members 80 and 90 for accommodating torque detection coil 8 and temperature compensation coil 9. Thus, even after connecting input shaft 2 with output shaft 3 through torsion bar 4, not only surrounding members 6 and 7 that are fixed to input shaft 2, but also surrounded member 5 that is fixed to output shaft 3 and torque detection coil 8 and temperature compensation coil 9 that are fixed to housing 1 can be all mounted from the side of input shaft 2. This results in an enhancement in assembling workability.

[0063]

Moreover, since surrounding members 6 and 7 are fixed to input shaft 2, torque detection coil 8 on the side of input shaft 2 can be inserted after fixing both surrounding members 6 and 7, leading to easy fixing of both surrounding members 6 and 7 to input shaft 2.

[0064]

Further, temperature-compensation-side surrounding member 7 has a center portion formed with center hole 74 which allows input shaft 2 and the annular base of surrounded member 5 to pass therethrough, and windows 71 are radially formed at positions opposite to non-recessed parts 52 of surrounded member 5 so as to

communicate with center hole 74 and allow non-recessed parts 52 to pass therethrough. Thereby, surrounded member 5 can pass axially through temperature-compensation-side surrounding member 7. Thus, after fixing surrounded member 5 to output shaft 3, a surrounding-member assembly having torque-detection-side and temperature-compensation-side surrounding members 6 and 7 integrated together through outer cylinders 63 and 73 can be inserted and disposed from the side of input shaft 2 to assemble surrounding members 6 and 7 in such a way as to hold surrounded member 5 from the sides of both axial faces of surrounded member 5. This results in a further enhancement in assembling workability.

[0065]

Still further, torque-detection-side surrounding member 6 is fixed to input shaft 2 by caulking inner-periphery-side cylinder 60 in circumferential groove 2d and concave 2f previously formed in the outer peripheral surface of maximum outer-diameter portion 2c of input shaft 2. This allows fine adjustment of sensor output obtainable by adjusting the positional relationship between surrounded member 5 and torque detection coil 8 and temperature compensation coil 9. The above-mentioned caulking is carried out after this fine adjustment of sensor output. Thereby, the relative rotation and axial movement can be prevented from occurring between input shaft 2 and both surrounding members 6 and 7.

[0066]

Furthermore, before caulking surrounding member 6 to input shaft 2; operation to be carried out is to loosely fit

inner-periphery-side cylinder 60 to the outer periphery of input shaft 2, and no press-fit operation is required. Accordingly, sure prevention of plastic deformation and the like of inner-periphery-side cylinder 60 are obtained, resulting in restraint of a reduction in detection accuracy obtained by the torque sensor.

[0067]

Referring to FIGS. 19 and 20, when the outside-air temperature of torque sensor varies, a stress is generated at caulked part 60a to provide a sufficient coupling force between caulked part 60a and circumferential groove 2d and concave 2f.

[0068]

Specifically, the caulking is carried out at an ordinary temperature of about 20° C. In this state, the protruding inner surface of caulked part 6a caused by plastic deformation is in press contact with opposed faces 2h and 2h of circumferential groove 2d, obtaining strong coupling by great frictional resistance (interference).

[0069]

When the atmospheric temperature (outside-air temperature) of torque sensor is, for example, very cold temperature of -40° C or low temperature of 0° C, inner-peripheral-side cylinder 60 is greater in contraction-deformation amount than input shaft 2, thus obtaining the whole inner peripheral surface of cylinder 60 in press contact with the outer peripheral surface of input shaft 2. Particularly, caulked part 60a has slightly reduced friction resistance with opposed faces 2h and 2h by contraction

deformation of cylinder 60. However, radial stresses generated at a point A (about -40° C) and a point B (about 0° C) as shown in FIG. 19 are increased to the side of a bottom 2g of circumferential groove 2d as shown by hatched triangles in FIGS. 20A and B. As a result, a friction resistance is increased between the bottom of caulked part 60a and bottom 2g of circumferential groove 2d, obtaining a sufficient tightening (coupling force) at caulked part 60a.

[0070]

On the other hand, when the atmospheric temperature is greater than an ordinary temperature, i.e. about 30° C or 40° C, inner-periphery-side cylinder 60a produces expansion deformation in the diameter increasing direction, reducing a tightening force of inner-periphery-side cylinder 60 to the outer peripheral surface of input shaft 2. However, an axial stress generated at caulked part 60a is increased as shown in FIG. 19. Accordingly, at a point C and a point D in FIG. 19, a friction resistance between both sides of the protruding inner surface of caulked part 60a and opposed faces 2h and 2h of circumferential groove 2d is increased as shown in hatched triangles in FIGS. 20C and D, obtaining a strong coupling force at caulked part 60a.

[0071]

Specifically, the expansion amount of each caulked part 60a and its part 60b is greater than the diameter increasing amount of circumferential groove 2d and concave 2f, providing axial interference. With this, the part 60b of each caulked part 60a is tightly fitted and

engaged in concave 2f, obtaining strong coupling. This allows sure prevention of axial and circumferential free rotation of cylinder 60, resulting in restraint of a reduction in detection accuracy obtained by the torque sensor.

[0072]

Further, annular spacer 10 is interposed between both yoke members 80 and 90 to determine an axial clearance between torque detection coil 8 and temperature compensation coil 9, allowing assembling of torque detection coil 8 and temperature compensation coil 9 with the positional relationship therebetween maintained, resulting in easy fulfillment of clearance control between both yoke members 80 and 90 (both coils 8 and 9).

[0073]

Still further, as described above, assembling of torque sensor TS is carried out, preferably, such that after connecting input and output shafts 2 and 3 through torsion bar 4, the sensor members such as torque detection coil 8 and the like are inserted to input and output shafts 2 and 3 for assembling. Namely, when connecting input shaft 2 with output shaft 3, pin mounting hole 2g is necessary to be formed to fix the upper end of torsion bar 4 to input shaft 2 by pin 2c, which produces a contaminant such as chip and cutting oil. Thus, in the case where input and output shafts 2 and 3 are connected with each other after inserting the sensor members such as torque detection coil 8; there is a fear that contaminant, cutting oil, and the like are adhered to the sensor member such as torque detection coil 8.

[0074]

Therefore in this embodiment, as described above, before assembling of all the sensor members such as torque detection coil 8 and the like from the side of input shaft 2; pin mounting hole 2g is formed to fix the upper end of torsion bar 4 to input shaft 2 by pin 2c, and pin 2c is fixedly fitted therein. Accordingly, contaminant, cutting oil, and the like can be prevented from adhering to the sensor members such as torque detection coil 8.

[0075]

Furthermore, recesses 80e and 90e and axial protrusions 22 and 23 are arranged between both yoke members 80 and 90 and spacer 10 to prevent relative rotation therebetween, allowing assembling with coil harnesses 8a and 9a of coils 8 and 9 aligned with each other with respect to the direction of protrusion. And positioning protrusions 24a and 24b and axial engagement groove(s) 122 are arranged between spacer 10 and upper housing 110 to prevent relative rotation therebetween, allowing the protruding positions of coil harnesses 8a and 9a of coils 8 and 9 to be aligned with wiring box 110e of upper housing 110 when assembling. This results in an enhancement in assembling workability.

[0076]

Further, fixing of both yoke members 80 and 90 to housing 1 is carried out at stationary flange parts 80d and 90d protruding outwardly from the opening edges located on the side of outer-periphery surrounding parts 80c and 90c of the main bodies of gate-shaped cross section for surrounding the both surrounding members 6 and 7 and the coils except their faces opposite to surrounded member 5.

Thus, both yoke members 80 and 90 can be fixed to housing 1 without varying an internal stress of the main bodies which form the magnetic paths in yoke members 80 and 90, resulting in achievement of a desired torque detection accuracy.

[0077]

Still further, fixing of yoke members 80 and 90 to housing 1 is carried out under the state where yoke members 80 and 90 are axially biased at both stationary flange parts 80d and 90d having spacer 10 interposed therebetween, by disc spring 12 and base member 11. Thus, only the arrangement of disc spring 12 allows easy assembling of yoke members 80 and 90 to housing 1 without varying an internal stress of the main bodies which form the magnetic paths in yoke members 80 and 90. Moreover, the biasing force of disc spring 12 allows prevention of positional deviation of both yoke members 80 and 90 (torque detection coil 8, temperature compensation coil 9).

[0078]

Furthermore, fixing of both yoke members 80 and 90 to housing 1 is carried out under the state where yoke members 80 and 90 are axially biased at both stationary flange parts 80d and 90d having spacer 10 interposed therebetween, through base member 11 provided in the axial direction. With this, only change of base member 11 allows easy change in axial mounting position of both yoke members 80 and 90 (torque detection coil 8, temperature compensation coil 9) with respect to housing 1,

surrounding members 6 and 7, and surrounded member 5 without having design modification of housing 1 itself.

[0079]

It is noted that the present invention is not limited to the configurations of above-described embodiment, and design modifications and the like according to the present invention can be made without departing from the scope of the present invention.

[0080]

By way of example, in the above embodiment, the surrounding member is arranged on the side of input shaft 2, whereas the surrounded member is arranged on the side of output shaft 3. Optionally, the reverse arrangement of this may be employed.

[0081]

Moreover, in the above embodiment, operation of forming pin mounting hole 2d and press fitting pin 2c therein is carried out after assembling housing 1. Optionally, this operation may be carried out before assembling the housing 1.

[0082]

In addition to Claims, a technical idea obtainable from the above embodiment is now described below.

[0083]

The electric power steering apparatus as claimed in one of Claims 1 and 2, wherein the caulked portion of surrounding member corresponding to the concave extends along and inside the circumferential groove.

[0084]

According to such invention, when the atmospheric temperature of the torque sensor is high; because of heat expansion, the interference between the surrounding member and the peripheral walls of the circumferential groove is enhanced, i.e., the caulked portion is tightly fastened also in the circumferential groove in addition to the axial groove. Thus, the coupling force is further enhanced.

[Brief Description of Drawings]

[FIG. 1]

A schematic view showing an electric power steering apparatus to which a torque sensor according to the present invention is applied.

[FIG. 2]

A longitudinal sectional view showing the electric power steering apparatus.

[FIG. 3]

An exploded perspective view showing the electric power steering apparatus according to an embodiment of the present invention.

[FIG. 4]

A perspective view showing a surrounded member in the electric power steering apparatus.

[FIG. 5]

An enlarged fragmentary sectional view showing the electric power steering apparatus.

[FIG. 6]

A fragmentary plan view showing a spacer provided in the embodiment.

[FIG. 7]

A sectional view taken along the line A-A in FIG. 6.

[FIG. 8]

A front view showing an input shaft in the electric power steering apparatus.

[FIG. 9]

A longitudinal sectional view showing a torque-detection-side surrounding member fixed to the input shaft by caulking.

[FIG. 10]

A sectional view taken along the line B-B in FIG. 9.

[FIG. 11]

An enlarged view showing a portion C in FIG. 10.

[FIG. 12]

A sectional view taken along the line D-D in FIG. 11.

[FIG. 13]

A sectional view taken along the line E-E in FIG. 11.

[FIG. 14]

A sectional view showing an inner-periphery-side cylinder portion caulked by a caulker.

[FIG. 15]

(A) is a side view of the caulker. (B) is a front view of the caulker.

[FIG. 16]

A plan view showing both surrounding members in the torque sensor.

[FIG. 17]

A sectional view taken along the line F-F in FIG. 14.

[FIG. 18]

A perspective view showing the both surrounding members in the torque sensor.

[FIG. 19]

A characteristic view illustrating a temperature-stress relation at a caulked part.

[FIG. 20]

(A) to (D) are conceptual views each showing stress distribution of the caulked part against the input shaft when having a change in temperature. (A) is under very cold temperature, (B) is under low temperature, (C) is under high temperature, and (D) is under very hot temperature.

[Expression of reference signs]

SW ... Steering wheel

TS ... Electric power steering apparatus

1 ... Housing

2 ... Input shaft (shaft member)

2d ... Circumferential groove

2e ... Axial groove

2f ... Concave (intersection part)

3 ... Output shaft

5 ... Surrounded member

6 ... Torque-detection-side surrounding member (cylindrical member)

6a ... Main body

7 ... Temperature-compensation-side surrounding member

8 ... Torque detection coil

9 ... Temperature compensation coil

60 ... Inner-periphery-side cylinder portion

60a ... Caulked part

60b ... One part

80 · 90 ... Yoke member

[Name of Document] Drawings

1 ... Housing
2 ... Input shaft
2d ... Circumferential groove
2e ... Axial groove
2f ... Concave
3 ... Output shaft
5 ... Surrounded member

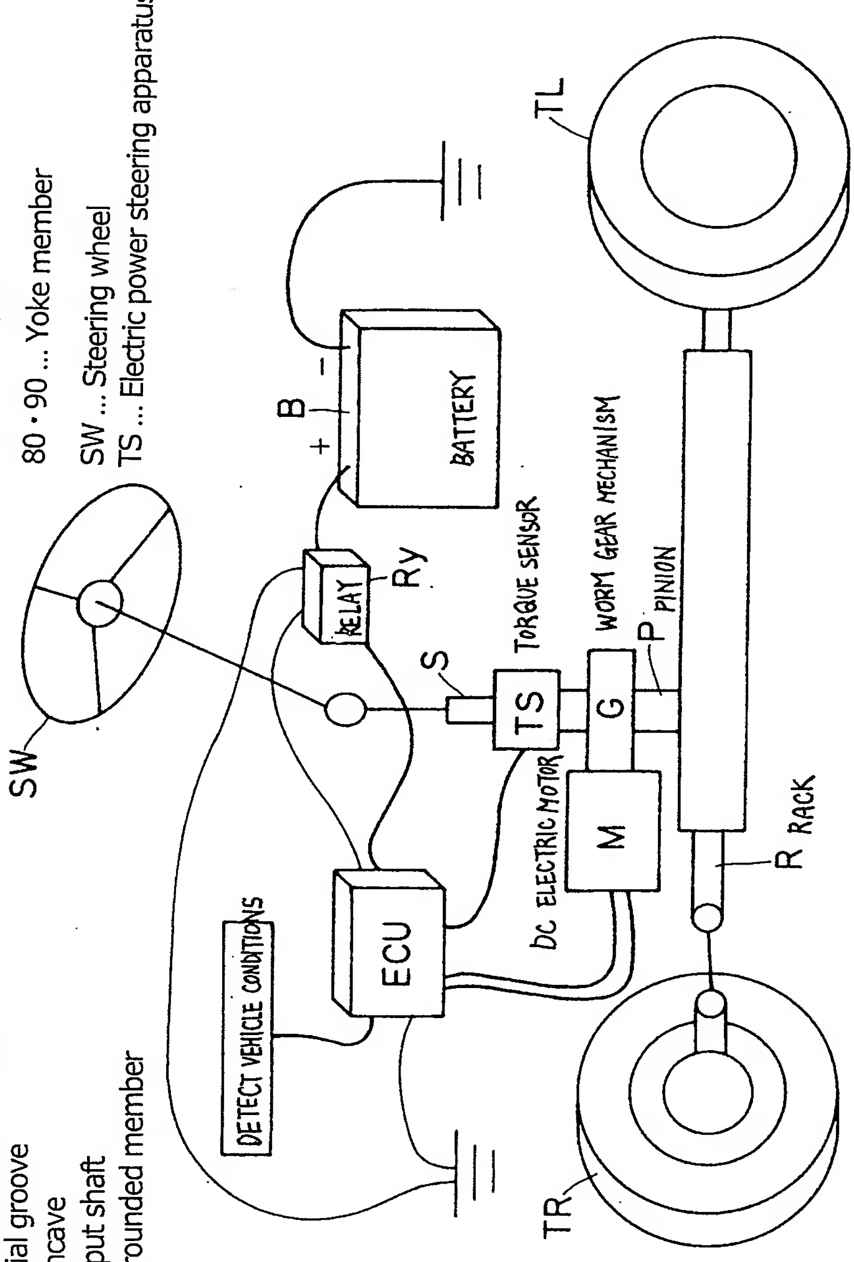
6 ... Torque-detection-side surrounding member
6a ... Main body
7 ... Temperature-compensation-side surrounding member

8 ... Torque detection coil (detection coil)
9 ... Temperature compensation coil (detection coil)
60 ... Inner-periphery-side cylinder portion
60a ... Caulked part
60b ... One part

80・90 ... Yoke member

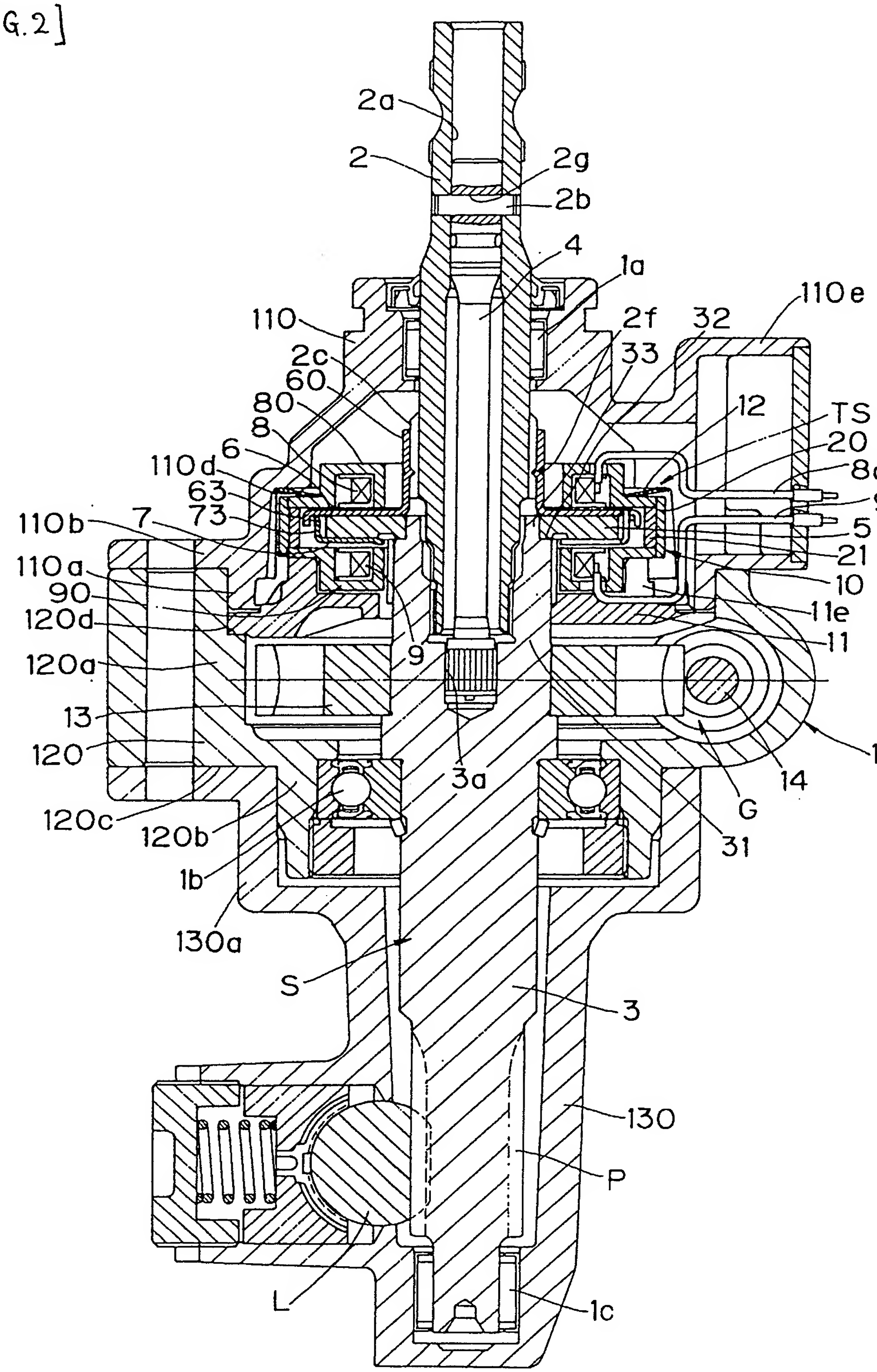
SW ... Steering wheel
TS ... Electric power steering apparatus

[FIG. 1]



~~【図２】~~

[FIG.2]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2
2g
2b
4
1a
110e
110
2f
32
2c
33
60
80
12
TS
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20
6
8a
110d
9a
63
73
5
110b
7
21
110a
10
90
11e
120d
11
120a
9
13
1
120
3a
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G
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S
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P
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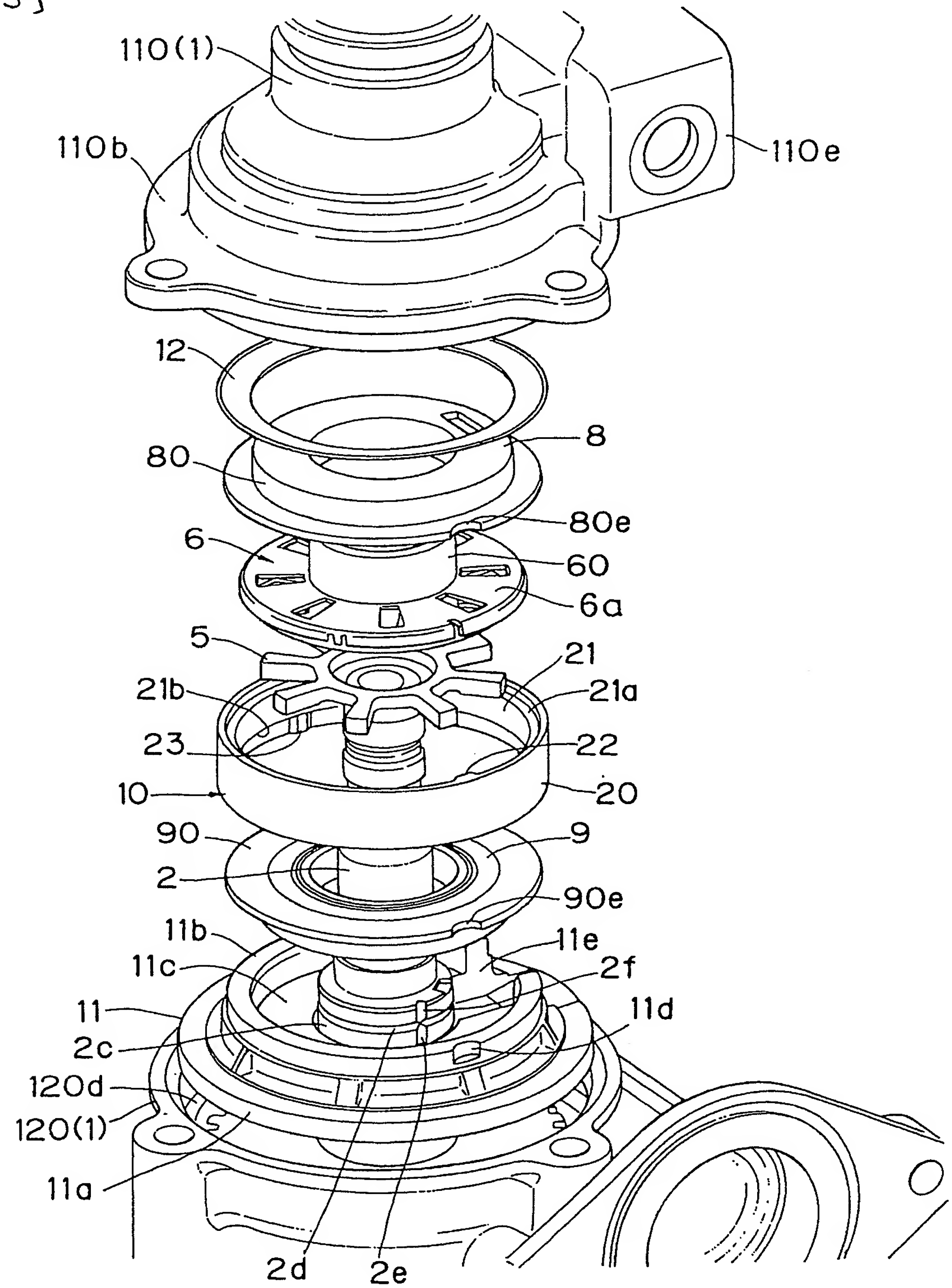
1c

~~【図３】~~
[FIG. 3]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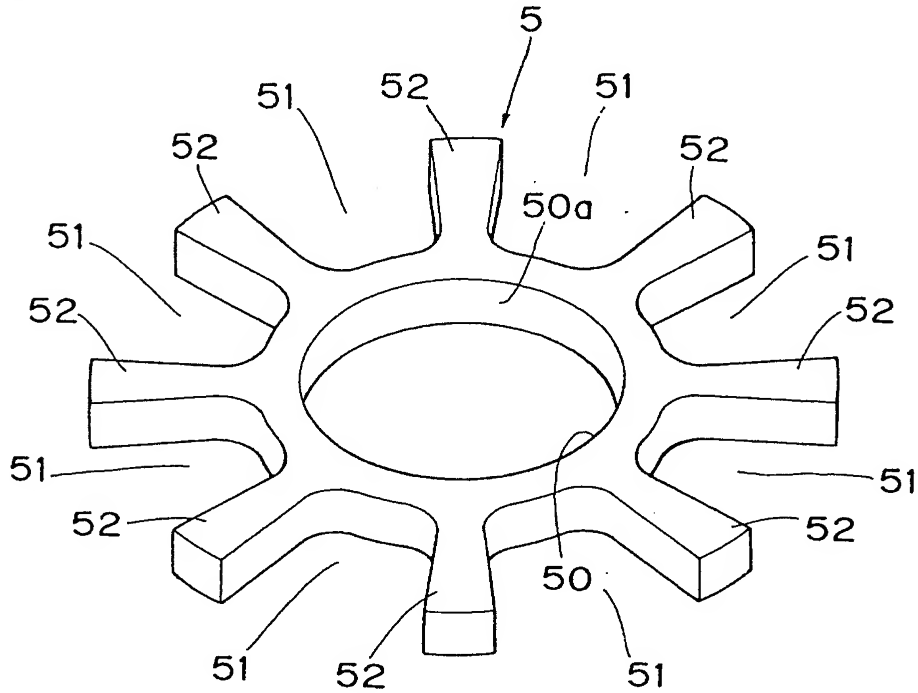
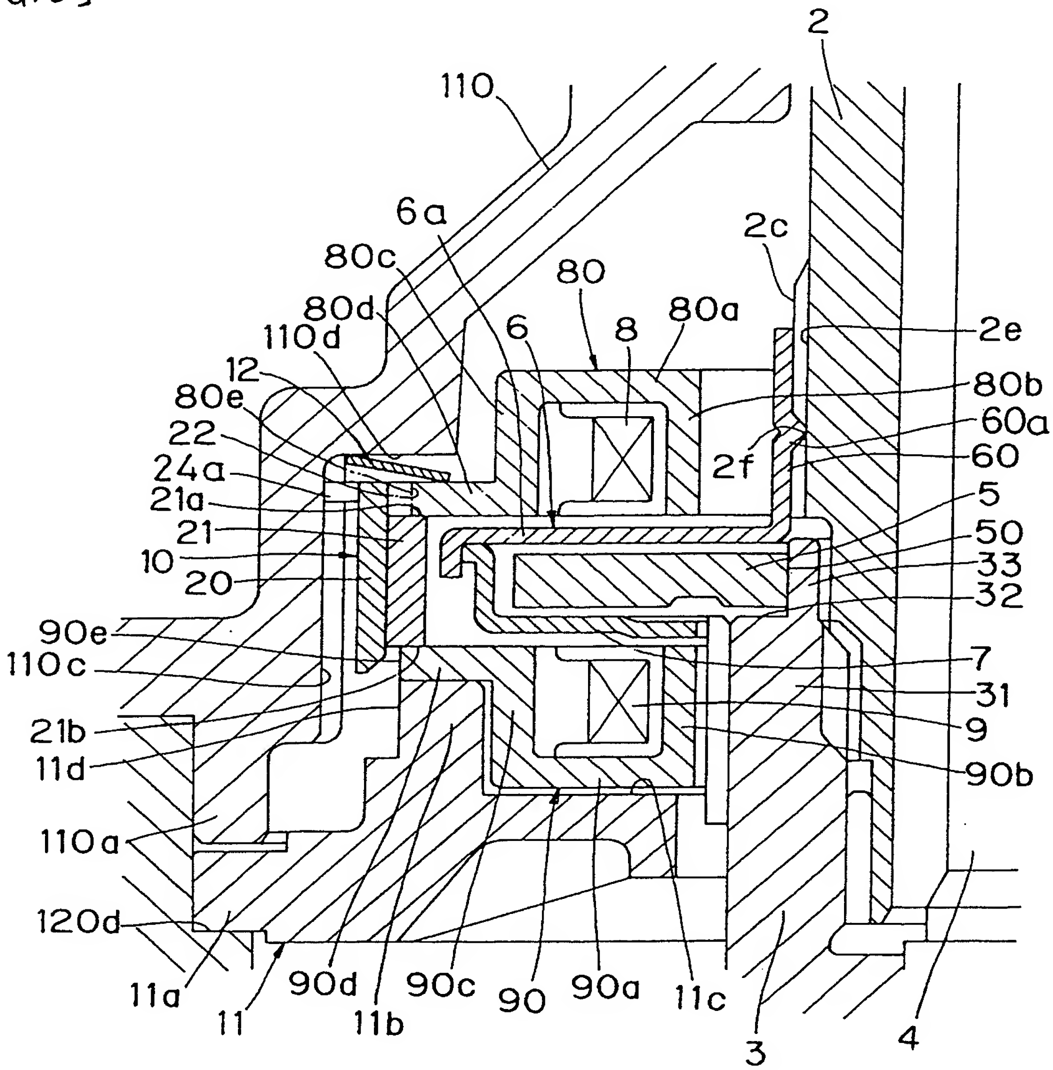
110e
12
8
80
80e
6
60
6a
5
21
21b
21a
23
22
10
20
90
9
2
90e
11b
11e
11c
2f
11
11d
2c
120d
120(1)
11a
2d
2e

~~【図４】~~
[FIG.4]



~~【図５】~~
[FIG.5]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24a
5
21a
50
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33
10
20
32
90e
7
110c
31
21b
9
11d
90b
110a
120d
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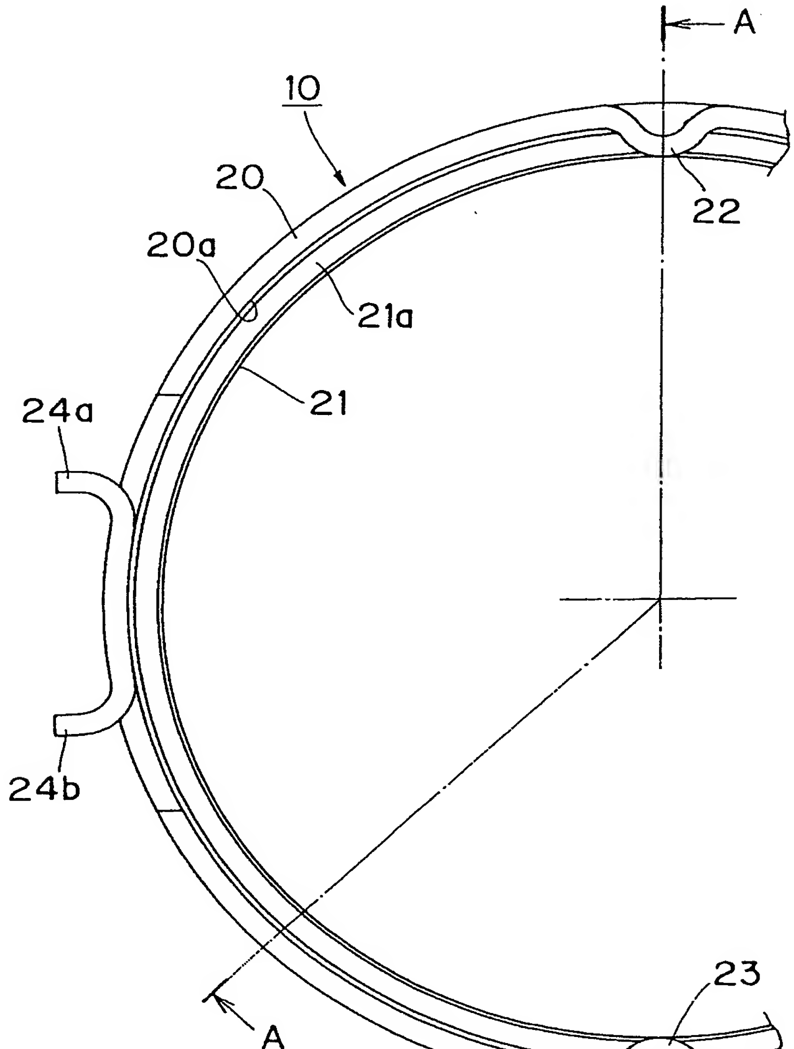
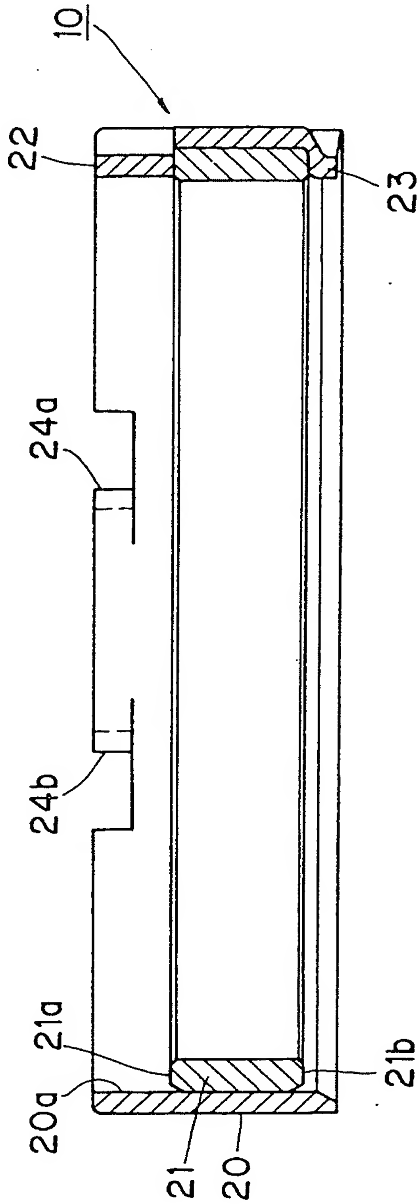
11b
90c
90
90a
11c
3
4

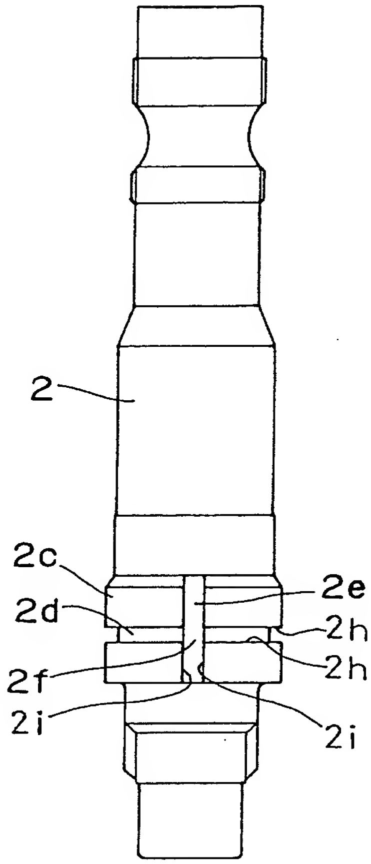
~~【図６】~~
[FIG. 6]



~~【図７】~~
[FIG.7]

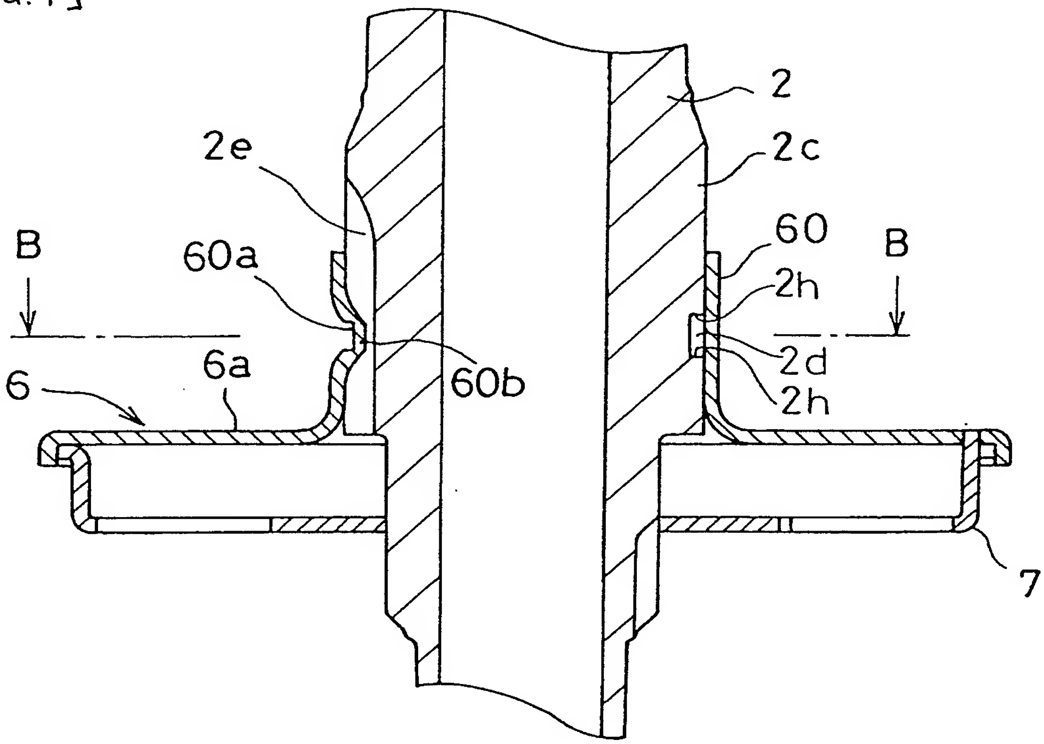


~~【図８】~~
[FIG.8]



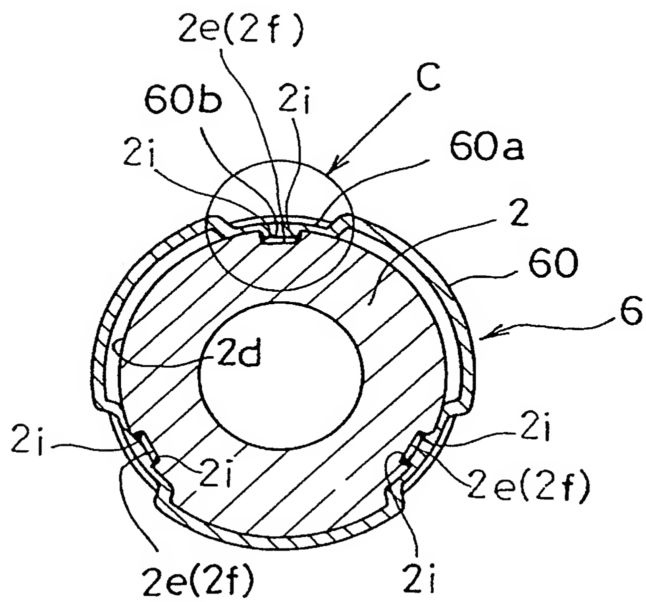
~~【図９】~~

[FIG.9]

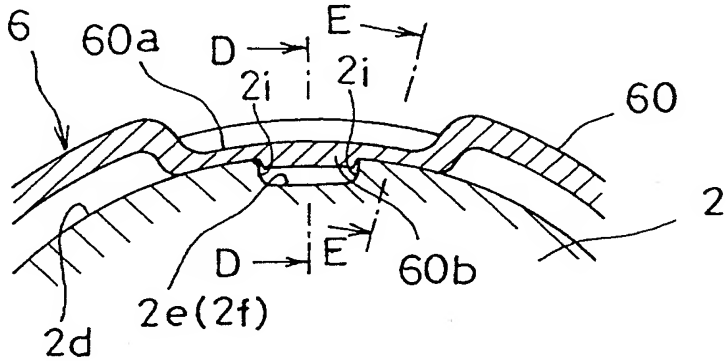


~~【図１０】~~

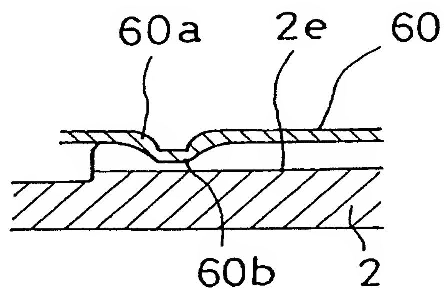
[FIG.10]



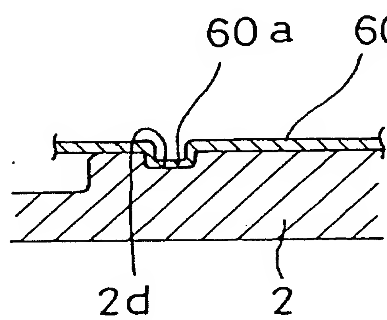
~~【図１１】~~
[FIG.11]



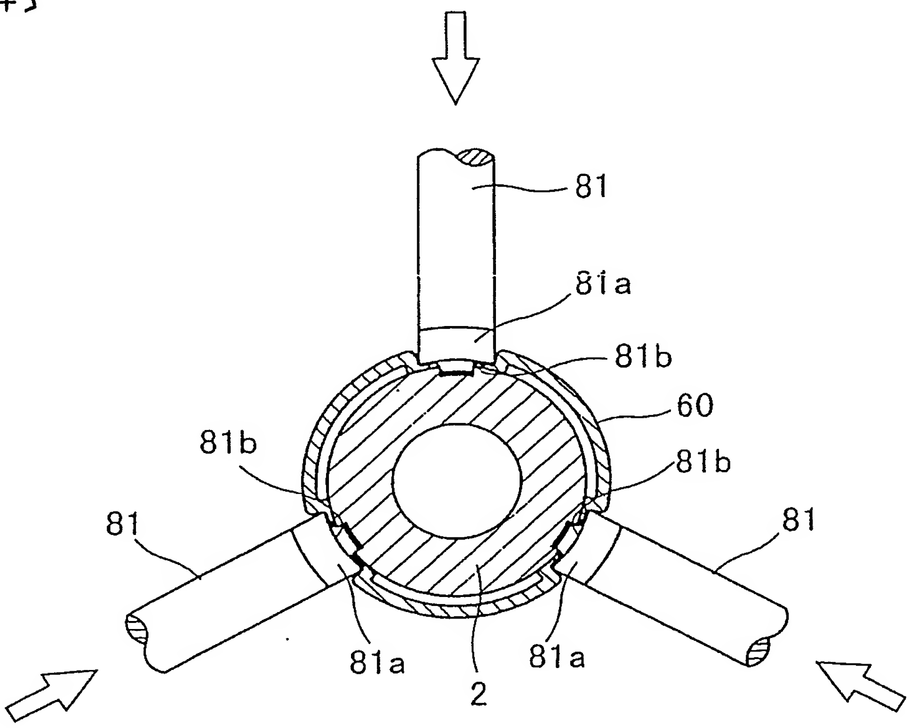
~~【図１２】~~
[FIG.12]



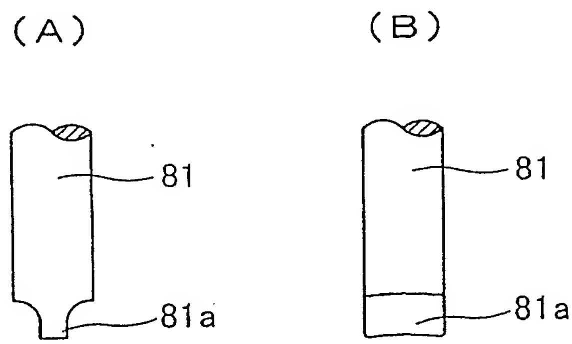
~~【図１３】~~
[FIG.13]



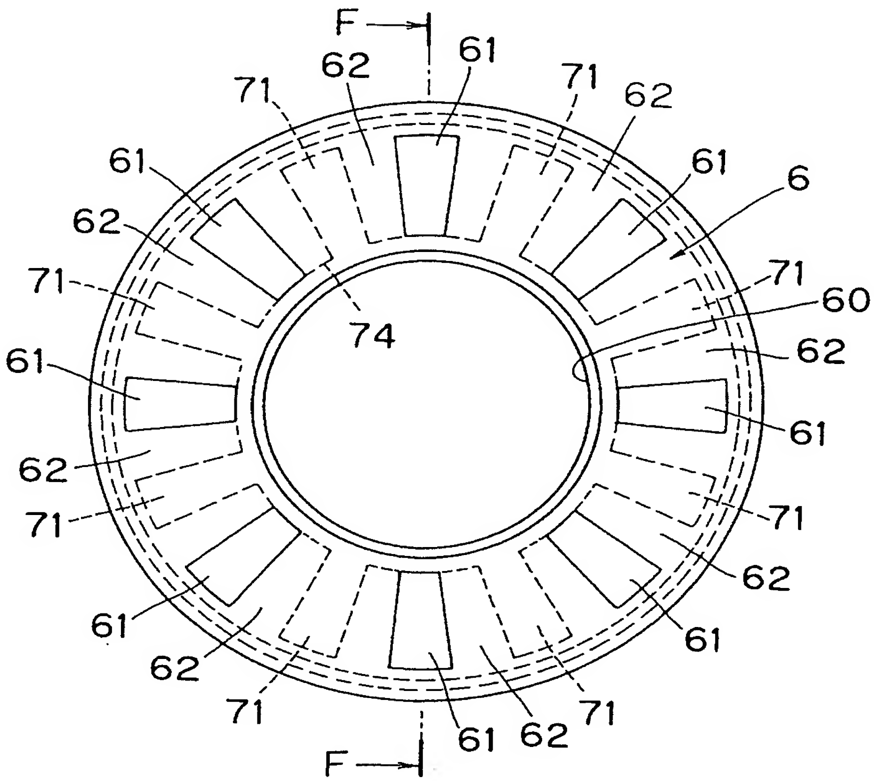
~~【図１４】~~
[FIG.14]



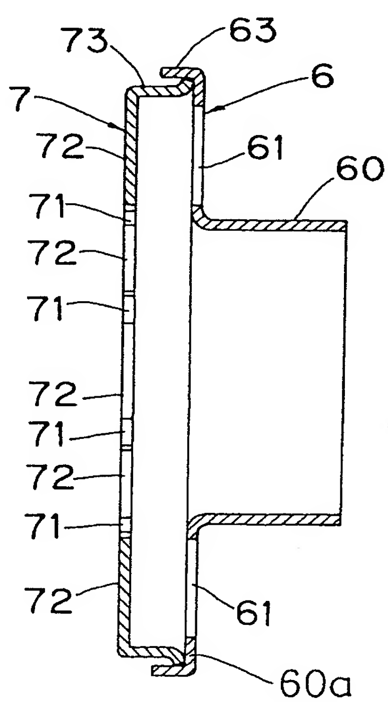
~~【図１５】~~
[FIG.15]



~~【図１６】~~
[FIG.16]

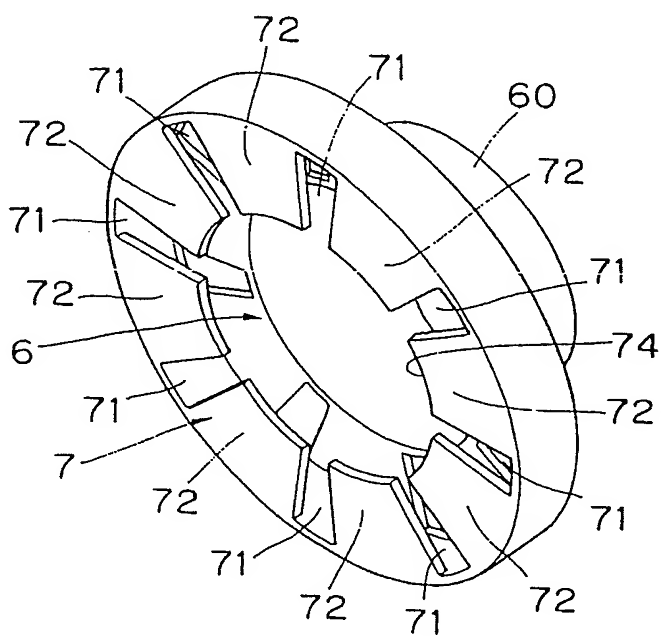


~~【図１７】~~
[FIG.17]



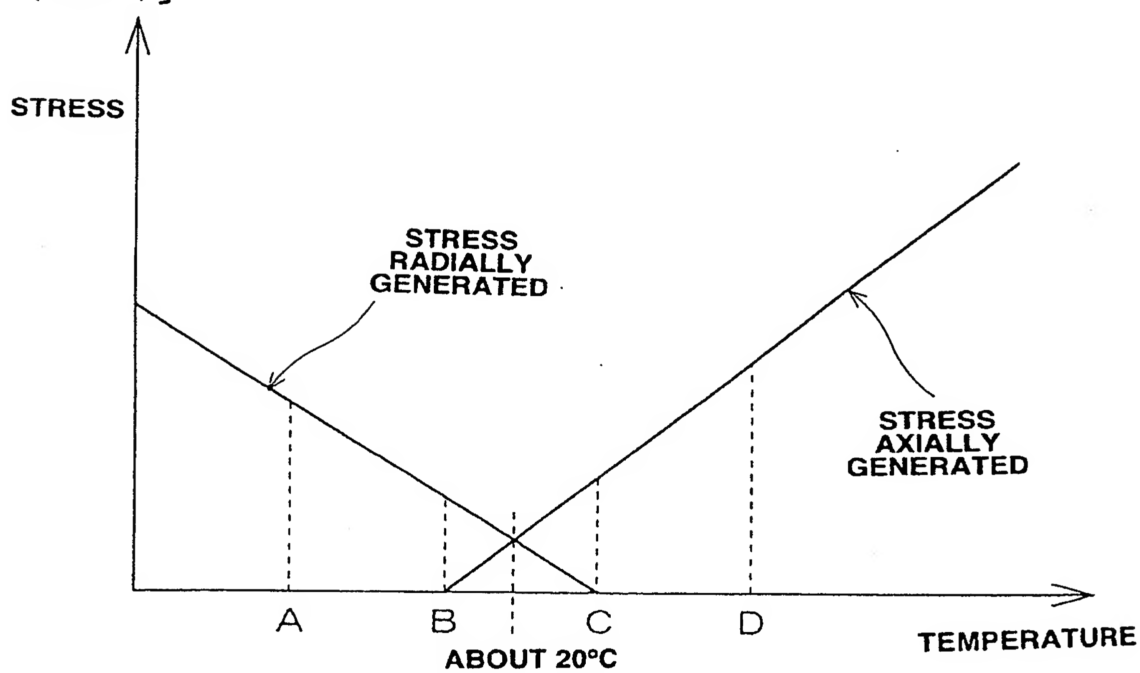
~~【図１８】~~

[FIG.18]

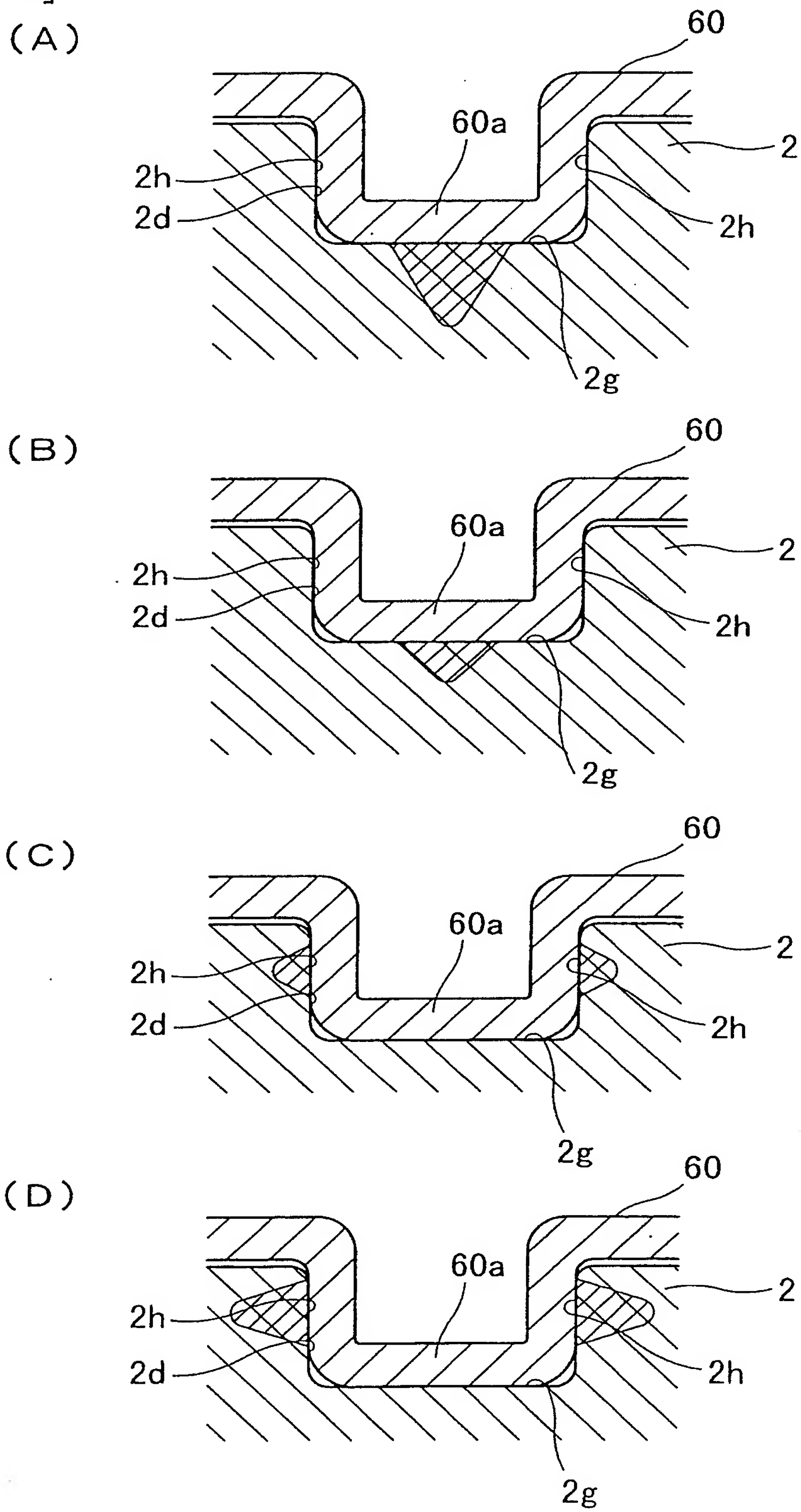


~~【図１９】~~

[FIG.19]



~~【図２０】~~
[FIG.20]


(A)
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60a
2
2h
2d
2h
2g
(B)
60
60a
2
2h
2d
2h
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(C)
60
60a
2
2h
2d
2h
2g
(D)
60
60a
2
2h
2d
2h
2g

[Name of Document] Abstract

[Abstract]

[Purpose] To prevent a plastic deformation of a torque-detection-side surrounding member when combining the torque-detection-side surrounding member to an input shaft side, and thereby to prevent the worsening in detection accuracy of a torque sensor.

[Solution] There are provided an input shaft 2 rotatably connected with an output shaft substantially coaxially with the output shaft; and a substantially-tubular torque-detection-side surrounding member 6 attached integrally with an outer peripheral surface of the input shaft, and provided with a torque detection coil on the outer peripheral side. Accordingly, torque generated between the both shafts is detected by allowing the detection sensor to detect a change of magnetic field due to the relative rotation between the input and output shafts. An axial groove 2e and a circumferential groove 2d intersecting with the axial groove are formed in the outer peripheral surface of the input shaft 2. When assembling the surrounding member, an inner-side cylindrical portion 60 of the surrounding member is fitted over the input shaft. Then, the inner-side cylindrical portion is caulked on a concave 2f, i.e., an intersection between the axial groove and circumferential groove, and a portion of the circumferential groove, and thereby the caulked portion 60a and its part 60b are connected therein under a depressed state.

[Selected Drawing] Fig. 10